**Greece 2.0**

**Basic Research Financing Action**

**(Horizontal support of all Sciences)**

**Sub-action 1**

**Funding New Researchers**

**PART B2.1**

# Part B2.1 Research Proposal

**Precise oRbit dEtermination and Positioning using satEllite doppleR obsErvations**

**PREPARE**

* **Principal Investigator** (Name/Surname): **Dimitrios Anastasiou**
* Scientific Area: SA2. Engineering Sciences & Technology
* Scientific Field: 2.1 Civil, Surveying & Architectural engineering
* Scientific Subfield: 2.1.7 Other
* Project Duration (in months): 24
* Total Budget (€): 190 000
* Host Institution: National Technical University of Athens
* Cooperating Organization(s): (*if applicable*)



## Excellence, State-of-the-art and Objectives

### Introduction

Geodesy has greatly advanced since the introduction of artificial, Earth orbiting satellites. A new era has emerged, where satellite-based data dominate the field, providing results for a wide range of geodesy-related fields, including but not limited to positioning, reference frames, altimetry and gravity field determination. Exploitation of satellite-based observations though, is inherently coupled with the complex problem of orbit determination.

Orbit determination offers unprecedented insight in the field of geodesy. Its contribution can be broadly grouped in a twofold role:

* As a product (i.e. tabulated satellite coordinates and/or velocity) it is needed for most spaced-based applications. Knowledge of satellite position (or state) is a prerequisite for most applications and in general dictates the quality of the application’s outcome. It should be noted that despite the extended demand for accurate satellite coordinates in recent years (mainly due to GNSS), the product list is by no means exhausted here; several other estimates constitute orbit determination products, as are e.g. earth orientation parameters, crucial for reference frame studies.
* As a field of study, it enables the testing, validation and improvement of models and theoretical aspects for various scientific disciplines, geodesy being the first and foremost beneficiary.

In this project, the second point above is targeted, i.e. the orbit determination methodology, as a means to deliver products of geodetic quality.

Given the composition of the research team and the available resources at hand, we strongly believe the proposal’s aims will be accomplished within the requested period of 24 months. The research team has an extensive, solid background and expertise on space geodesy and especially the analysis of satellite-based observations. It possesses knowledge of state-of-the-art methodologies on data processing and is actively involved in applications of space-geodetic techniques demanding the utmost precision.

### Relevance with the selected Scientific Area

*Please write you text here…*

### Proposal objectives and necessity/challenges

The current proposal's objective is the design and implementation of a state-of-the-art, open-source and free software module to perform precise orbit determination and positioning using the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) satellite system.

Within the framework of the project, three satellites will be targeted, namely

* the Joint Altimetry Satellite Oceanography Network – 3 (Jason-3)
* the Sentinel-3A and
* the Hai Yang 2C (HY-2C)

satellites

Via the resulting software, NTUA will be able to provide:

* Precise orbit products for the selected satellite missions.
* High quality position estimates for the DORIS-system ground segment (beacons)
* Estimates for a number of parameters of geodetic and/or atmospheric interest

#### The Jason-3 satellite

Jason-3 is a satellite mission that supports scientific, commercial and practical applications related to sea level rise, ocean circulation, and climate change. It is an international cooperative mission in which NOAA is partnering with the Centre National d'Etudes Spatiales (CNES, France’s governmental space agency), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and National Aeronautics and Space Administration (NASA) [1].

#### The Sentinel 3-A satellite

Sentinel-3A is a European Space Agency Earth observation satellite dedicated to oceanography. It will provide, ocean, inland sea and coastal zone color measurements, sea surface temperature measurements and sea surface topography measurements (altimetry) including an along track SAR capability [2].

#### The Hai Yang 2C satellite

The Hai Yang 2C is developed and operated by China. It's mission is to monitor and investigate the marine environment, and obtain marine dynamic environmental parameters including sea surface wind, wave height, sea surface height, etc. HY-2C could directly provide measured data for early warning of disastrous sea conditions and provide services for marine disaster prevention and mitigation, marine rights maintenance, marine resource development, marine environmental protection and marine scientific research [3], [4].

#### Objectives

The objectives of the targeted satellite missions can only be achieved in the presence of high quality space vehicle orbits. Measurements performed by their onboard instruments can only be used in high precision applications, if the satellite's position is known to a required accuracy. Hence, the necessity of precise orbit determination is profound, inherent to the mission's success.

Among other instruments, the payload of the satellites includes DORIS receivers to enable precise orbit determination. However, only a few Analysis Centers worldwide can process observations of this system. According to the International DORIS Service (IDS), the last contribution of the Service to the latest International Terrestrial Reference Frame (ITRF2020, [5]) included analysis results from no more than four Analysis Centers ([6]), each one using their own, in-house software package.

This scarcity of both Analysis Centers and respective software (In comparison, for the other two prominent space-based orbit determination techniques, the International GNSS service includes twelve Analysis Centers [7] and the International ILRS Service includes seven core and a number of Associate Analysis Centers [8]) underlines the need for high-caliber scientific teams targeting this challenging technique, thus further strengthening its contribution to both earth-based (e.g. the ITRF realizations) and space-based (e.g. orbits) products.

On the other hand, this scarcity is also a proof of concept for the challenges posed in performing high quality analysis using the DORIS system. Processing system observations requires expertise in various multi-disciplinary fields (e.g. astrodynamics, geodesy, atmospheric physics, etc), claiming optimal decisions between models and methodologies, design and implementation, in an ever-upgrading field. Precise orbit determination and positioning constitutes one of the most complex and demanding problems in Satellite Geodesy, one that is always evolving due to its multi-disciplinary nature and the ever-growing disposal of satellite missions and data.

### State-of-the-art and Innovation

Currently, only four such software packages exist ([6]) worldwide, but are neither open source, nor free. The objective of the proposed project is to design and implement an orbit determination and positioning software tool using DORIS data, introducing on the way novel approaches, and validating state-of-the-art methodologies. We aim at a robust methodology providing quality satellite state estimates, one though that can be efficient enough to be implemented for near-real time applications. Hence, algorithmic design and implementation, as well as efficiency and resource awareness are all topics to be considered.

Guidelines set by the IDS act as the de-facto standard for orbit determination via DORIS. We will try to comply with this set of recommendations as close as possible, deviating when needed to check and validate alternate or novel processing approaches.

[6] Using measured satellite attitude (satellite body orientation in the quaternion form and solar panel angles) instead of nominal attitude results in slightly better POD results

Indicative fields should include:

* Relevance with the selected Scientific Area
* Proposal objectives and necessity/challenges
* State-of-the-art & Innovation
* Scientific and/or social impact

## Methodology and Implementation

*Indicative fields should include:*

* *Research Methodology*
* *Work Plan*
* *Research Team*

### Research Methodology

*Please write you text here…*

### 

### Work Plan (Work Packages, Gantt Chart, Deliverables and Milestones Table, Table of Risks and Contingency Plan}

*Please include the following:*

*- Brief outline of the overall work plan.*

*- Description of each Work Package (WPs).*

*- Tables of Deliverables and Milestones.*

*- Table of Risks and Contingency Plan.*

*- Timeline/timetable of the different work packages and their components (Gantt Chart).*

#### Brief outline of the overall work plan

*Please write your text here…*

#### Description of each Work Package (WPs)

*Indicative Table for the description of each Work Package.*

*[****Important:*** *Please include a Project Management and a Dissemination and Communication Management Work Package]*

|  |  |  |
| --- | --- | --- |
| **WP Number: 1** | **WP Title: Refactoring** | |
| **Starting Month: 1** | **Ending Month: 3** | **Person Months (PMs):** |
| Objectives: It is important to integrate state-of-art research into the methodologies to be implemented in precise orbit determination using doppler observations from different satellites. The research team will gain extensive knowledge of existing techniques. In this working package, we will determine software development strategies and specifications.  Description of Work: The team will investigate the algorithms and technological development so far, with regard to doppler data analysis. It will explore and study related software and tools. At the end of this working package the standards and specifications for the development software will be decided.  Tasks: Define software development standards and implementation strategy.  Deliverables: D1.1 – Software specifications  Milestones: M1.1 – Software specifications | | |

|  |  |  |
| --- | --- | --- |
| **WP Number: 2** | **WP Title: Core Software Development** | |
| **Starting Month: 3** | **Ending Month: 12** | **Person Months (PMs):** |
| Objectives: The research team will design and develop a new, state-of-art, open source, software module to perform precise orbit determination and positioning using the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) satellite system.  Description of Work: Design and development of the core part of the new software for doppler observations analysis. In this working package all the necessary algorithms and routines for the processing will be developed and they are independent of the specific satellites.  Tasks: The first beta version of the software will be developed and released.  Deliverables: D2.1 – Software release v1.0b1  Milestones: M2.1 – Software release v1.0b1 | | |

|  |  |  |
| --- | --- | --- |
| **WP Number: 3** | **WP Title: Attitude and phase low implementation** | |
| **Starting Month: 13** | **Ending Month: 20** | **Person Months (PMs):** |
| Objectives:  Description of Work:  Tasks:  Deliverables: D3.1 – Software Release v1.0b4  Milestones: M3.1 – Software Release v1.0b2, M3.2 – Software Release v1.0b3, M3.3 – Software Release v1.0b4 | | |

|  |  |  |
| --- | --- | --- |
| **WP Number: 4** | **WP Title: Software Testing and Data Processing** | |
| **Starting Month: 16** | **Ending Month: 24** | **Person Months (PMs):** |
| Objectives: The goal is the validation and evaluation of the software and algorithms implemented in Working Packages 2 and 3. In this Working Package, historic data processing for precise orbit determination will take place in parallel.  Description of Work: The necessary bug fixes and upgrades will be integrated in the software suits. Final release v1.0 will be published. Updates will be based on the results of data processing.  Tasks: Updates and bug fixes will be integrated into final (v1.0) release of the software suites. The data will be processed with the software developed in the previous packages. We will also process the data using existing software packages and compare the results.  Deliverables: D4.1 – Software release v1.0, D4.2 Results of Data Processing  Milestones: M4.1 – Validation of Software Release v1.0b1, M4.2 – Validation of Software Release v1.0b4, M4.3 – Software Release v1.0, M4.4 – Data Processing | | |

|  |  |  |
| --- | --- | --- |
| **WP Number: 5** | **WP Title: Validation of geodetic parameters and Time series analysis** | |
| **Starting Month: 21** | **Ending Month: 24** | **Person Months (PMs):** |
| Objectives:  Description of Work:  Tasks:  Deliverables:  Milestones: | | |

|  |  |  |
| --- | --- | --- |
| **WP Number: 6** | **WP Title: Dissemination and communication management** | |
| **Starting Month: 6** | **Ending Month: 24** | **Person Months (PMs):** |
| Objectives: Dissemination of project results in the technical and scientific community through presentations, publications and a school/workshop.  Description of Work: Part of the project will be the dissemination of research results and discussion with the scientific community on new solutions and approaches introduced. A website will be developed to promote the project and disseminate the new software. A school/workshop will be organized especially for young researchers in order to learn about the new software and the possibilities that it will provide. Overall, the projects aim to contribute to the development of a research network in Greece and in collaboration with the international scientific community regarding the utilization of the DORIS system. Finally, the results will be presented to the students of the Host Institute (NTUA) or other technical universities.  Tasks: The software will be accessible on a free software repository under an opensource license. Members of the group will participate in two conferences and will write a peer reviewed paper in scientific journal. They will also organize a school/workshop oriented towards young researchers for the presentation of the new software and highlight new possibilities and collaborations.  Deliverables: D6.1, D6.2 – Conference presentations, D6.3 – Peer reviewed paper, D6.4 – School/Workshop Proceedings, D6.5 - Website | | |

|  |  |  |
| --- | --- | --- |
| **WP Number: 7** | **WP Title: Project Management** | |
| **Starting Month: 1** | **Ending Month: 24** | **Person Months (PMs):** |
| Objectives: Technical and financial management of the project. Observing work schedule.  Description of Work: Principal investigator supervises the work flow and financial management of the project. He is in direct contact with the managing authority and the Host Institute responsible for the progress of the project.  Tasks: Project management. Research team supervision. Control over expenditures and compliance with the targeted timetable and Working Plans.  Deliverables: D8.1 – Report for technical and financial management | | |

#### Deliverables

*Indicative deliverables: technical reports, research results, databases, new studies, interactive tools, e-learning tools, dissemination reports [peer-reviewed journals, publications in conference proceedings, books/chapters in books, lectures/conferences/workshops presentations), posters, patents etc.]*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Deliverable Number** | **Deliverable Name** | **Related WP** | **Type[[1]](#footnote-1)** | **Dissemination Level[[2]](#footnote-2)** | **Due Date**  **(in months)[[3]](#footnote-3)** |
| **D1.1** | Software specifications | 1 | R | CO | 3 |
| **D2.1** | Software Release v1.0b1 | 2 | DEM | CO | 12 |
| **D3.1** | Software Release v1.0b4 | 3 | DEM | CO | 20 |
| **D4.1** | Software Release v1.0 | 4 | DEM | PU | 21 |
| **D4.2** | Results of Data Processing | 4 | R | PU | 24 |
| **D5.1** | Technical Report WP5 | 5 | R | PU | 24 |
| **D6.1** | Conference presentation 1 | 6 | DEC | PU | 14 |
| **D6.2** | Conference Presentation 2 | 6 | DEC | PU | 21 |
| **D6.3** | Peer reviewed paper | 6 | DEC | PU | 21 |
| **D6.4** | School/Workshop Proceedings | 6 | DEC | PU | 24 |
| **D6.5** | Website | 6 | DEM | PU | 24 |
| **D7.1** | Report for technical and financial management | 7 | R | PU | 24 |

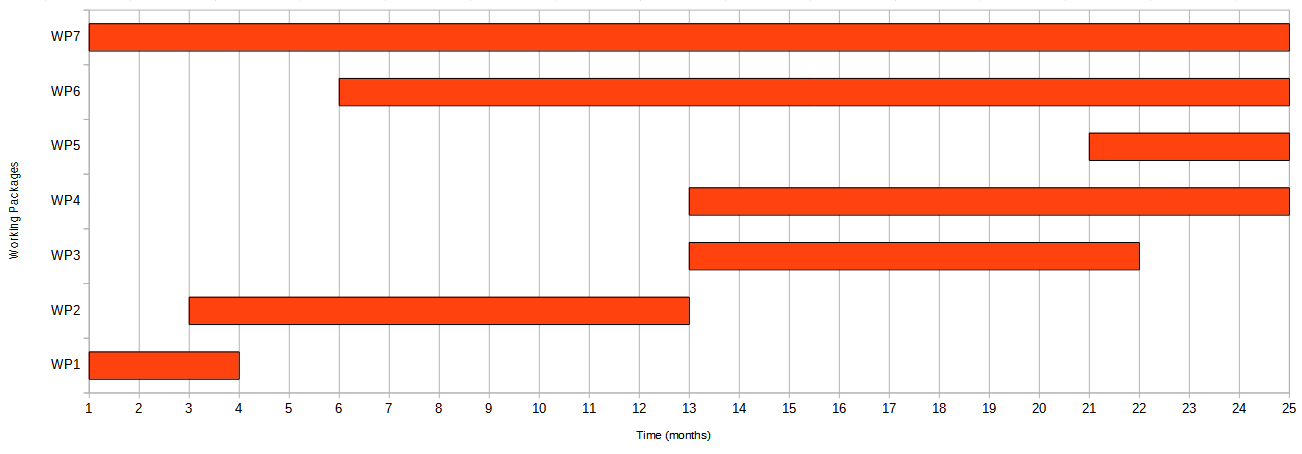
#### Milestones

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Milestone Number** | **Milestone Name** | **Related WP** | **Due Date**  **(in months)** | **Means of Verification** |
| **M1.1** | Software specifications | 1 | 3 | Report |
| **M2.1** | Software Release v1.0b1 | 2 | 12 | Beta Release |
| **Μ4.1** | Validation of Software release v1.0b1 | 4 | 13 | Report |
| **M3.1** | Software Release v1.0b2 | 3 | 16 | Beta Release |
| **M3.2** | Software Release v1.0b3 | 3 | 18 | Beta Release |
| **M3.3** | Software Release v1.0b4 | 3 | 20 | Beta Release |
| **Μ4.2** | Validation of Software release v1.0b4 | 4 | 21 | Report |
| **M4.3** | Software Release v1.0 | 4 | 21 | Release |
| **M4.4** | Data Processing | 4 | 21 | Products |
| **Μ5.1** | Validation of geodetic parameters | 5 | 23 | Report |

#### Risks and Contingency Plan

|  |  |  |
| --- | --- | --- |
| **Description of risk**  (indicate level of likelihood: Low/Medium/High) | **WPs involved** | **Proposed risk –Mitigation measures** |
| Administrative risk (Low) | All | Institutional capacity is guaranteed by EU funding |
| **Lost of satellite** | 3, 4, 5, 6 | **Use alternative** |
| **Attitude low not successfully determined** | 3, 4, 5, 6, 7 | **Lower accuracy** |

#### Timeline/timetable of the different work packages and their components (Gantt Chart).



### Research Team

Principal Investigator Assistant Professor Dimitrios Anastasiou will be involved in all Working Packages and he will be responsible for managing the project. He will decide on the design specifications of data analysis software. He will participate in code development and validation of the software release, as he has experience in data analysis methodologies. He will be responsible for the design of data processing, validation of geodetic parameters an time series analysis of ground permanent station of DORIS System. Additionally, he will have the technical and financial management of the project and he will participate in conferences and the writing of peer reviewed paper. Finally, he will be responsible for the organization of school/workshop.

Professor Maria Tsakiri ……..

Mr. Xanthos Papanikolaou is a PhD candidate specialized in GNSS and DORIS data processing, with software development expertise. He will participate in the design and implementation of the software suites by developing the code and evaluating it. He will handle bug fixes and updates for the software package. He will also take place in data processing and time series analysis of ground stations. He will participate in the conferences and writing the peer reviewed paper. Finally, he will present the software in the school/workshop with some test cases.

Mrs Vassiliki Krey is a new doctoral candidate who deals with the satellite systems and data processing. She has experience in DORIS system data processing as it was part of her diploma thesis. She will mainly participate in the development of the software package. She will participate in code development and its validation. She will also take part in data processing and time series analysis. Finally, she will take part in conferences and the peer reviewed paper as well as in the preparation, organization and the presentations of school/workshop.

Mr. Evangelos Zacharis is a member of the technical and research staff of Host Institute (NTUA). He has many years of experience in GNSS data processing and code development, and is recently specialized in atmospheric effects on the signal of DORIS satellite system. He will participate in the implementation of the software suites, in testing and evaluating them as well as in data processing.

## Budget

*Please complete/modify the following table to include all costs of the proposed project.*

**Table 3.1. Project Budget and justification**

|  |  |
| --- | --- |
| **Cost Category** | **Restrictions** |
| **DIRECT COSTS** |  |
| **Personnel costs1 (PI and Research Team members)** | **≥ 50% of the total budget** |
| **Consumables** | - |
| **Dissemination and Travel** | - |
| **Equipment (Depreciation value)** | - |
| **Other costs** | - |
| **Subcontracting costs** | **≤ 10% of the total budget** |
| **INDIRECT COSTS** | **≤15%**  **of personnel costs** |
| **Total HI Budget** | **€** |

*1For personnel costs please refer to the terms described in Table4 of the call.*

**Budget justification**

*Please justify the proposed costs per category here*

## REFERENCES

[1] "Jason-3 Satellite - Mission" (https://www.nesdis.noaa.gov/jason-3/mission.html).

Retrieved 10 October 2022.

[2] "Sentinel - Mission Objectives" (https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-3/mission-objectives)

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[3] "China launches ocean monitoring satellite", Spaceflight Now, October 10, 2022

[4] "National Satellite Ocean Application Service, HY-2C" (http://www.nsoas.org.cn/eng/item/253.html), Retrieved 10 October 2022.

[5] "The International Terrestrial reference Frame: an update", Z. Altamimi, Fifteenth Meeting of the International Committee on Global Navigation Satellite Systems (ICG), 2021

[6] "The international DORIS service contribution to ITRF2020", G. Moreaux, F. G. Lemoine, H. Capdeville, M. Otten, P. Štěpánek, J. Saunier, P. Ferrage, Advances in Space Research, 2022

[7] "Analysis Center Coordinator, IGS Analysis Centers", https://igs.org/acc/, Retrieved 10 October 2022.

[8] "ILRS Analysis Centers", https://ilrs.gsfc.nasa.gov/science/analysisCenters/index.html, Retrieved 10 October 2022.

[9] "Impact of nominal and measured satellite attitude on SLR- and DORIS-derived orbits of Jason satellites and altimetry results", S. Rudenko, J. Zeitlhöfler, M. Bloßfeld and D. Dettmering, Ocean Surface Topography Science Team Meeting (OSTST) 2019, 21-25 October 2019, Chicago, Illinois, United States of America

[10] "DORIS results on Precise Orbit Determination and on geocenter and scale solutions from CNES/CLS IDS Analysis Center contribution to the ITRF2020", H. Capdeville, J-M. Lemoine, A. Mezerette and G. Moreaux, EGU21-5384, G2 - Reference Frames and Geodetic Observing Systems, G2.4 - Precise Orbit Determination for Geodesy and Earth Science

[11] "IDS Recommendations and suggestions for ITRF 2020 reprocessing", International DORIS Service, https://ids-doris.org/images/IDS\_RecommendationsITRF2020\_04.02.2020.pdf, Retrieved 10 October 2022.

1. Please add one of the following types:

   **R** = Report (document, including interim and final report)

   **DEM** = Demonstrator (prototype, plan, etc.)

   **DEC** = Publications, patents, etc.

   **Other** [↑](#footnote-ref-1)
2. Please add one of the following types:

   **PU** = PUBLIC (public available)

   **CO** = CONFIDENTIAL (available only to the research team and H.F.R.I.) [↑](#footnote-ref-2)
3. *Please add the respective Project’s delivery month.* [↑](#footnote-ref-3)